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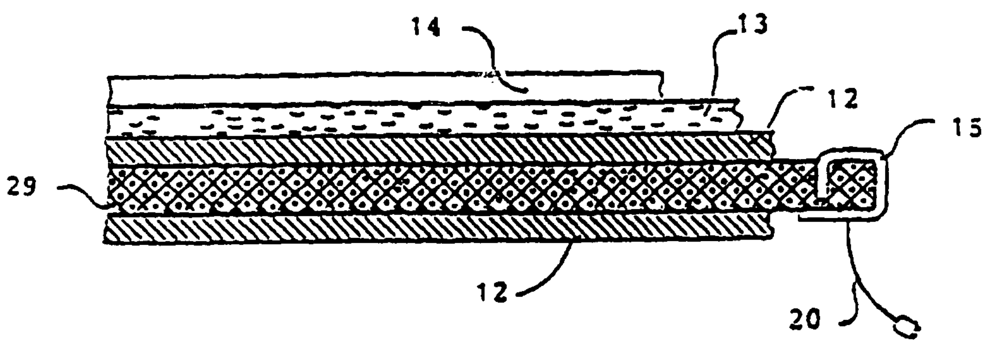

(57) Abstract

A soft and flexible thin heating element made of electrically conductive carbon carrying fabric is impregnated with a soft filling material. The heating element (29) is shaped by curing the soft filling material and cutting the treated fabric into a desired pattern. The electrical contacts (15) are attached to the ends of the serpentine strips which are electrically connected in parallel or in series. The fabric heating element core (29) is sealed to form a multi-layer assembly having at least two electrically insulating layers (12) which envelop each strip of the heating element core. The heating element is made of non-metallic yarns containing electrically conductive carbon/graphite containing fibers which are woven or stranded into the strips, ropes, sleeves or strands of threads. The selected areas of the heating element core are modified to impart additional electrical properties. An optional positive temperature coefficient (PTC) material is incorporated into said selected areas.

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HEATING ELEMENT AND METHOD OF MANUFACTURE

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to heating elements, and more particularly to heating elements which are soft, flexible, flat, strong, light and thin, and to their method of manufacture.

2. Description of the Prior Art

Heating elements have extremely wide applications in household items, construction, industrial processes, etc. Their physical characteristics, such as thickness, shape, size, strength, flexibility and other characteristics affect their usability in various applications.

Numerous types of thin and flexible heating elements have been proposed, for example U.S. patent 4,764,665 to Orbat et al. This heating element, however, is made of a solid piece of fabric with metallized coating, it does not allow for flexibility in selection of desired power density and is not economical due to metallizing process. The '665 design is also not conducive to hermetic sealing through the heater areas which can cause a short circuit through puncture and admission of liquid. This element can't be used with higher temperatures due to the damage that would be caused to the metallized fabric.

Another prior art example is U.S. patent 4,538,054 to de la

Dorwerth. However, the heating element of de la Dorwerth '054 suffers from the following drawbacks: its manufacturing is complex requiring weaving of metal or carbon fibers into non-conductive fabric in a strictly controlled pattern; the use of the metal wire can result in breakage due to folding and crushing and it affects softness, weight and flexibility of the finished heater; it can't be manufactured in various shapes, only a rectangular shape is available; only perimeter sealing is possible, which can result in a short circuit due to puncture and admission of a liquid; the method of interweaving of wires and fibers doesn't result in a strong heating element, the individual wires can easily shift adversely affecting; the fabric base of the heating element is flammable and may ignite as a result of a short circuit; it is not suitable for high temperature applications due to destruction of the insulating weaving fibers at temperatures exceeding 120°C.

U.S. patent 3,627,988 describes a method of assembling a surface heater based on carbon fibers consisting of attachment of continuous non-woven carbon fiber material to contact electrodes and to the shape forming layers of fabric by sewing with a thread. The disadvantages of this method are as follows: this method doesn't allow the flexibility of creating heating elements of various shapes and sizes; the manufacturing process is complex and produces hazardous dust during the sewing operation; application of pressure to the surface of the heating element, made of non-woven carbon fabric, significantly increases its electro-conductivity, which, in turn, changes its intended properties;

after a period of use under the effect of mechanical forces the non-woven material tends to separate and to form localized lumps affecting usability and performance; this method produces a heater with significant thickness.

Further, attempts have been made to fabricate electrically heated systems from carbon fibers, yarns, and fabrics by coating the carbon material with a protective layer of elastomer or other materials to overcome carbon's extremely poor abrasion and kink resistance (Carbon Fibers for Electrically Heated Systems, by David Mangelsdorf, final report 6/74 - 5/75, NTIS). It was found that the coating used in this method reduced the carbon material flexibility and increased the difficulty of making electrical attachments to it, and making electrically continuous seams. The poor flexibility of coated carbon fabric made this material unsuitable for small and complex assemblies, such as handware.

U.S. patent 4,149,066 to Niibe et al describes a sheet-like thin flexible heater made with an electro-conductive paint on a sheet of fabric. This method has the following disadvantages: the paint has a cracking potential as a result of sharp folding, crushing or punching; the element is hermetically sealed only around its perimeter, therefore lacking adequate wear and moisture resistance; such an element can't be used with high temperatures due to destruction of the underlying fabric and thermal decomposition of the polymerized binder in the paint; the assembly has 7 layers resulting in loss of flexibility and lack of softness.

Additionally, a known method of achieving a flexible flat

heating element is by surfacing threads of fabric with carbon particles and various polymers as disclosed in U.S. patent 4,983,814. The resulting heating elements have necessary electro-physical characteristics, but their manufacturing is complex and is ecologically unfriendly because of the use of organic solvents, such as diethylphormamide, methylethylketone and others. Furthermore, this method involves application of an electro-conductive layer only to the surface of threads of fabrics. This layer, electro-conductivity of which is achieved through surface contact of extremely small particles, is susceptible to damage due to external factors, such as friction, bending, etc.

Another prior art example is U.S. patent 4,309,596 to George C. Crowley, describing a flexible self-limiting heating cable which comprises two conductor wires separated by a positive temperature coefficient (PTC) material. Said heating wires are disposed on strands of nonconductive fibers coated with conductive carbon. This method has the following disadvantages: (a) the wires are enveloped and separated by the tough PTC material which thickens and hardens the heating element (b) the distance between the wires is very limited, due to a nature of the PTC material having a high electrical resistance, this prevents manufacturing of heaters with large heat radiating surface; (c) the heater is limited only to one predetermined highest temperature level, therefore, this heating device is unable to bypass said temperature level when a quick heating at the highest temperature is needed.

The present invention seeks to alleviate the drawbacks of the

prior art and describes the fabrication of both a carbon carrying fabric heating element and a non-metallic yarn which are economical to manufacture; don't pose environmental hazards; and result in a soft, flexible, flat, strong, thin, and light heating element, suitable for even small and complex assemblies, such as handware. A significant advantage of the proposed patent is that it provides for fabrication of heating elements of various shapes and sizes, with predetermined electrical characteristics; allows for a durable heater, resistant to kinks and abrasion, and whose electro-physical properties are unaffected by application of pressure, sharp folding, punches, small punctures, small cuts and crushing.

SUMMARY OF THE INVENTION

The first objective of the invention is to provide a significantly safe and reliable heating element which can function properly after it has been subjected to sharp folding, kicking, small punctures, punching or crushing, thereby solving problems associated with conventional flexible heating wires. In order to achieve the first objective, the electric heating element, of the present invention, is made of a carbon carrying conductive fabric or carbon/graphite electrically conductive yarns which possess the following characteristics: (a) high strength; (b) high strength-to-weight ratio; (c) high thermal and electrical conductivity; (d) very low coefficient of thermal expansion; (e) non-flammability; and (f) softness. The proposed invention comprises continuous or electrically connected separate strips of carbon carrying fabric,

which radiate a uniform heat over the entire heating surface, thus preventing occurrence of overheated spots. An additional embodiment is comprised of continuous or electrically connected separate strips, sleeves, ropes or strands of carbon/graphite yarns, which radiate a uniform heat over the entire heating core surface.

A second objective of the invention is to provide maximum flexibility and softness of the heating element. In order to achieve the second objective, the electric heating element comprised of carbon carrying conductive fabric is made of a very thin (.1 to 3mm, but preferably within the range of 0.2-2.0mm) woven or non-woven carbon carrying fabric, which is cut into continuous or electrically connected strips and patterned to have gaps between the strips. The electric heating element comprised of carbon/graphite electrically conductive yarns contains thin (.05 to 5.0 mm, but preferably within the range of 0.1-2.0 mm) threads, which are woven or stranded into continuous or electrically connected strips, sleeves/pipes, ropes or bundles, then arranged and insulated to have gaps between the electrically conductive media. Furthermore, all the components of the multi-layer heating element assembly are thin, soft and flexible materials.

A third objective of the invention is to provide for the uniform distribution of heat without overheating and hot spots, thereby solving the problem of over insulation and energy efficiency. In order to achieve this objective, one side of the heating element includes a metallic foil or a metallized material

to provide uniform heat distribution and heat reflection. A thin layer of such electro-conducting heat reflecting material is placed above the electro-insulating material prior to lamination to prevent direct electrical contact of metal with the conductive fabric. It is also preferable that the soft heating elements of the invention are made without thick cushioning insulation, which slows down the heat delivery to the surface of the heating apparatus.

A forth objective of the invention is to provide for ease in the variation of heating power density utilizing the same type of conductive fabric, thereby solving a problem of manufacturing various heating devices with different electric power density requirements. In order to achieve the forth objective, the carbon carrying conductive fabric is stabilized by impregnation with soft filling substances and then cut to desired patterns. The soft filling material can also be used to augment the electro-physical characteristics of the carbon carrying fabric. In the modified embodiment, the yarns in the heating element core are woven or stranded into strips, ropes, sleeves/pipes or bundles with predetermined width, density of weaving and thickness. It is preferable that the strips, sleeves/pipes, ropes or strands are made of combination of yarns with different electrical resistance and/or include electrically nonconductive high strength polymer or ceramic fibers.

A fifth objective of the invention is to provide a reliable and strong electrical contact of the conductive fabric with

electrodes for electric power delivery, thereby solving a problem of providing a sufficient electrical contact between soft conductive fabric and metal electrodes during assembling of the heating element. In order to achieve the fifth objective, the contacts are made of thin metal foil, metallized polymer or thin rigid conductive electrodes which are attached to the ends of the carbon carrying fabric prior to lamination of insulating materials. The electrical contacts are glued to the carbon carrying fabric heating element core by the conductive adhesive and firmly attached to the fabric to provide a sufficient electrical conductivity. It is preferable that conductive adhesive is comprised of carbon/graphite or silver or nickel ingredients.

A sixth objective of the invention is to provide for ease of installation of the electric heating elements inside the heating devices, thereby solving a problem of complicated attachment of conventional heating wires over the desired working area of the flexible heating devices. In order to achieve the sixth objective, the insulated electric heating element is patterned and manufactured prior to installation to fit the whole desired area of the flexible heating device.

A seventh objective of the invention is to provide for ease in manufacturing of the heating element core comprised of carbon/graphite yarns, thereby eliminating a problem of impregnation of the whole fabric with stabilizing or filling materials to enable cutting to a desired pattern. In order to achieve the fifth objective, all strips, sleeves/pipes, ropes and

threads are woven or stranded into a desired stable shape prior to the heating element manufacturing.

An eighth objective of the invention is to provide a temperature self-limiting properties to the heating element core if dictated by the heater design thereby eliminating a need for thermostats. In order to achieve the sixth objective, the positive temperature coefficient (PTC) material is utilized in the selected areas of the heating element core.

The present invention comprises a heating element which is flat, thin, flexible, soft, strong and light. It is also highly resistant to abrasion, punctures, cuts, punches, sharp folding and crushing. It can be manufactured in various shapes and sizes, and it can be designed for a wide range of parameters, such as input voltage, desired temperature range, desired power density, type of current (AC and DC) and method of electrical connection (parallel and series). In one embodiment, a soft and flexible thin heating element made of electrically conductive carbon carrying fabric is impregnated with a soft filling material. The heating element is shaped by pressing, heat treating and cutting the fabric into a serpentine pattern. The electrodes are attached to the ends of the serpentine strips which are electrically connected in parallel or in series. The fabric heating element core is sealed to form a multi-layer assembly comprising of at least two electrically insulating layers which envelop each strip of the serpentine strips. The method of producing the soft and flexible heating element is also disclosed.

In a second embodiment, the heating element consists of electrically conductive carbon/graphite yarns woven or stranded into strips, ropes, sleeves/pipes or strands of threads. The selected areas of the heating element core are conditioned to impart a variety of electrical properties in said core. The conditioning of the soft woven heating element core may include a positive temperature coefficient (PTC) material to impart temperature self-limiting properties. The heating element core is shaped by folding or assembling of said conductive media into a predetermined pattern. The electrodes are attached to said heating element core and are electrically connected in parallel or in series. The soft heating element core is sealed to form an assembly containing at least one electrically insulating layer which envelops each strip, rope, sleeve/pipe or strand of threads.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view of the process of manufacturing the carbon carrying fabric with the soft filling material according to the present invention.

Fig. 2 is a perspective view of a heating element according to the preferred embodiment of the present invention.

Fig. 3 is an exploded view of the connection of the fabric, contact electrodes, and power cord.

Fig. 4 is a plan view of heating elements connected in series according to an embodiment of the present invention.

Figs. 5a and 5b are plan views of heating elements connected

in parallel according to another embodiment of the present invention.

Fig. 6 is a cross section view of a laminated heating element according to an alternate embodiment of the present invention.

Fig. 7 is sectional view of a process of applying insulation to a heating element according to an alternate embodiment of the present invention.

Fig. 8 is a sectional view of an insulated heating element according to an alternate embodiment of the present invention.

Figure 9A shows a plan view of the heating element core electrically connected in series according to the preferred embodiment of the present invention.

Figure 9B is a perspective view of the end of the heating element core showing connection of an electrode.

Figure 10A is a plan view of the heating element core electrically connected in parallel, where individual strips are shaped in zigzag pattern.

Figure 10B is a plan view of the heating element core electrically connected in parallel according to the preferred embodiment of the present invention.

Figure 11 is a perspective view of the insulated heating element core electrically connected in parallel, having electrical busses wrapped by the heating element core material and utilizing cut outs.

Figure 12A is a perspective view of a fragment of the heating element core electrically connected in parallel, having electrical

busses made of woven strips sewn or stapled to the heating element core and having PTC material incorporated longitudinally into said heating element core in selected areas.

Figure 12B is a perspective view of a fragment of the heating element core, electrically connected in parallel having electrical busses made of highly conductive threads or thin metal wires woven or sewn into its body and having PTC material incorporated longitudinally into said heating element core in selected areas.

Figure 13 shows a plan view of the heating element core having three bus conductors and a PTC material incorporated longitudinally into the body of said heating element core so as to separate two of three busses according to the preferred embodiment of the present invention; said busses are connected to a power source through a power controller.

Figure 14 shows a cross-section of the insulated heating element including separate fragments of the heating element core, having PTC material connecting said fragments and providing electrical continuity.

Figure 15 shows a cross-section of the insulated heating element including fragment of the heating element core where the bus electrode is enveloped by the PTC material according to the preferred embodiment of the present invention;

Figure 16 shows a perspective view of a fragment of the heating element core made of a strand or a rope of non-metallic fibers with varying electrical properties, having electrode connector attached to its end by crimping.

Figure 17A shows a perspective view of a sleeve/pipe shaped heating element core, having bus electrodes and electrically connected in series according to the preferred embodiment of the present invention.

Figure 17B shows a perspective view of a sleeve/pipe shaped heating element core, having bus electrodes and electrically connected in parallel according to the preferred embodiment of the present invention.

Figure 17C shows a perspective view of a sleeve/pipe shaped heating element core, having bus electrodes, electrically connected in parallel and having an optional PTC material incorporated into said heating element core according to the preferred embodiment of the present invention.

Figure 18A is a plan view of the back side of a garment including a soft heating element according to the present invention.

Figure 18B is a perspective view of a vehicle seat including a soft heating element according to the present invention.

Figure 18C is a perspective view of a floor assembly including a soft heating element according to the present invention.

Figure 18D is a perspective view of a fragment of pipe including a soft heating element according to the present invention wrapped around the pipe.

DETAILED DESCRIPTION OF THE INVENTION

The first embodiment of the present invention is detailed in

Figures 1 through 6. As shown in Figure 1 a carbon carrying fabric basis (11) is unrolled from the spool (17), advanced through the driving rollers (30) and is saturated in the impregnation basin (31) with a solution of soft filling material (21). The saturation in the impregnation basin (31) can be successfully substituted by spraying of the solution of soft filling material (21) or application of thin polymer film of the soft filling material at least from one side of carbon carrying fabric (11).

The excess soft filling material is than squeezed out by the rollers (19) with an adjustable pressure function; this allows for variation in the amount of the soft filling material left in the carbon carrying fabric depending on design parameters. The carbon carrying fabric (11) is then passed through the curing device (18) where it is subjected to heat and, if necessary, pressure to adequately set and cure the soft filling material (21).

The soft filling material acts as fabric stabilizer and enables cutting of the carbon carrying fabric into a desired shape. In addition it may be used to augment the electro-conductive characteristics of the base carbon carrying fabric (11). Therefore, the soft filling material (21) can include conductive particles like graphite, carbon black, or other metal carrying compounds. It is preferable to use nonvolatile oligomeric or polymeric compounds like starch, polyethylene, carboxymethylcellulose, polyurethane as soft filling materials (21).

As shown in Figure 2, a serpentine shape heating element core

(29) is cut out from the stabilized carbon fabric (11). It is preferable that the strips of the carbon fabric serpentine core (29) have an even width. The ends to which the electrodes shall be attached are cleaned of non-conductive material and an optional conductive adhesive or conducting filling material (16) is applied to them. Thin contact electrodes (15) are then attached to the ends of the heating element core (29).

As shown in Figure 3, the optional holding teeth (25) may be used to achieve a better contact between the fabric and the electrodes. A power cord (20), having a plug (26), is then attached to the contact electrodes (15) utilizing male (23) and female (24) connectors or other known methods which provide sufficient electrical contact.

As shown in Figure 4 and Figure 5, the electrical connection may be made in series or in parallel. An optional heat regulating thermostat (27) and power output adjustment device (22), may be installed, if required, by a listing agency or a design. The most appropriate patterns which allow efficient and economical trimming of the carbon carrying fabric (11) are zigzag and spiral shapes. The parallel connection can be accomplished either by connecting separate strips of the carbon carrying fabric (11) to a conductive bus bar (33) as shown in Fig. 5a, or by cutting the assembly in such a way that the carbon carrying fabric bus strips (34) located at opposite ends of the heating strips are continuous to the heating strips without a break in the carbon carrying fabric material (11) from which they were cut out. (Fig. 5b) In order to

provide for high electrical conductivity of the bus strips (34), which is necessary to assure a uniform current distribution through all strips of the heating core (29), the bus strips (34) can be augmented by one or combination of the following methods: affixing highly electro-conductive flexible strips (35) to at least one side of each bus strip (34); interweaving or sewing highly electro-conductive wires through each bus bar (34); or impregnating the bus strips (34) with a highly electro-conductive substance, including but not limited to graphite.

As shown in Figure 6, the assembly of heating element core (29), contact electrode (15) and the power cord (20) is then laminated between at least two layers of electro-insulating material (12) with an optional heat reflective layer (13) and a protective layer (14) adhered to heat reflective layer (13). The electro-insulating materials (12) envelop each strip of the heating element fabric core (29), hermetically sealing the gaps between said strips.

As shown in Fig. 7 and Fig. 8, the complete heating element assembly is then sealed by a pressure device (32) with or without application of heat. The electro-insulating materials (12) envelop each strip of the heating element fabric core (29) sealing the gaps between said strips. A low temperature sealing consists of application of electro-insulating materials (12) having heat resistant adhesive (28) at least on one side of electro-insulating materials (12) facing the heating element fabric core (29). A high temperature sealing consists of heating of electro-insulating

materials (12) which results in their fusing in the gaps between the strips of the heating element fabric core (29).

A flexible-in-all-directions thin heating element can be utilized for all varieties of commercial and industrial heaters utilizing direct or alternative current. The main advantages of the heating element are the high reliability and safety which are provided by the tightly sealed soft and durable conductive fabric.

Furthermore, the heating element has additional advantages in that the thin fabric:

enables manufacturing of the thin, soft and uniform heaters without installation of disturbing conventional heater wires;

provides high durability of the heating appliances which can withstand sharp folding, punches, punctures, small cuts and compression without decreasing of electrical operational capabilities;

provides high tear and wear resistance owing to: (a) high strength of the conductive fabric, (b) enveloping around all of the fabric serpentine pattern with the polymer insulating material;

provides high moisture resistance owing to: (a) impregnating of the soft filling material which prevents or significantly slows down penetration of the moisture through the fabric core, (b) sealing of the gaps between the fabric core serpentine by the polymer insulating materials;

provides for manufacturing of corrosion and erosion resistant heating element owing to: (a) high chemical inertness of the carbon carrying fabric and (b) hermetic polymer insulation of the whole

heating element including connection electrodes and temperature control devices, in utilization in chemically aggressive industrial or marine environments;

offers versatility of variation of the electrical conductivity of the fabric core owing to: (a) cutting of desired serpentine pattern of the conductive fabric, (b) impregnation with the soft filling material having different amount of conductive ingredient, (c) carbon carrying fabric having different amount of conductive fibers per unit volume [Example: different type and density of weaving], (d) carbon carrying fabric having different level of carbonizing of the fibers;

provides for saving of electric power consumption owing to: (a) installation of heat reflective layer and (b) possibility of placing the heat element with less cushioning and insulation closer to the human body or to the heated object;

allows for manufacturing of heating element with electrical connection of electrically conductive strips in parallel or in series;

overcomes the problem of overheated spots owing to (a) high heat radiating surface area of the fabric core, (b) uniform heat distribution by the heat reflective and heat conductive layer preventing the possibility of skin burns or destruction of the insulating polymer layers;

provides for extremely low thermal expansion of the heating element owing to the nature of the carbon carrying fabric. This feature is extremely important for construction applications

(Example:-concrete) or for multi-layer insulation with different thermal expansion properties;

consists of a non combustible conductive fabric which does not cause arcing while being cut or punctured during electrical operation;

offers high degree of flexibility and/or softness of the heating appliances depending on the type and thickness of insulation; and

provides technological simplicity of manufacturing and assembling of said heating element.

The process of manufacturing of the insulated heating element can be fully automated, it utilizes the commercially available non toxic and inexpensive products. The insulated fabric core can be manufactured in rolls with subsequent cutting to desired sizes and further attachment of electric power cords.

The aforementioned description comprises different embodiments which should not be construed as limiting the scope of the invention but, as merely providing illustrations of some of the presently preferred embodiments of the invention. Additional contemplated embodiments include: (a) the conductive fabric can include other electrically conductive materials other than carbon, such as electroplated copper, nickel or tin containing coatings on the surface of the carbon carrying fibers; (b) the electrically conductive fabric can consist of ceramic fibers, such as alumina, silica, zirconia, chromia, magnesium, calcia or a combination thereof, coated or impregnated with electrically conductive

material such as carbon; (c) the soft filling material can consist of different oligomeric or polymeric compounds, such as polyurethane, polyvinyl-containing products, etc.; (d) the conductive fabric can be cut out into separate strips and subsequently electrically connected to each other in a serpentine form or other desired patterns, including ordinary straight or "U" shaped strips; (e) the electric power cord can be attached to the conductive fabric without electrodes by directly connecting of the cord by conductive adhesive, conductive paint, conductive polymer, etc.; (f) the conductive fabric heating element can be electrically insulated by other soft non conductive fabrics by sewing, gluing, fusing etc., forming a soft multi-layer assembly; (g) the conductive fabric core of the heating element can be electrically insulated by rigid non-conductive materials like ceramics, concrete, thick plastic, wood, etc.; (h) the conductive fabric heating element can be assembled in combination with other types of known flexible heating elements like heating wires.

The second embodiment of the invention consists of a non-metallic heating element core made by assembling yarns comprising carbon/graphite fibers as shown in Figures 9-18. The core is woven into various longitudinal forms during textile fabrication, such as strips, sleeves, pipes and ropes. It may also take a form of a strand of threads. The heating element core may, along with electrically conducting carbon/graphite fiber yarns, contain other, electrically non-conducting, yarns in various proportion and weaving patterns in order to augment its electrical

resistance. Such yarns have at least one of the following contents:

1. Yarns made of carbon/graphite carrying fibers with similar electrical characteristics.

2. Yarns made of carbon/graphite carrying fibers with varying electrical characteristics.

3. Yarns, as indicated in 1 or 2 above, with addition of ceramic, including fiberglass, fibers.

4. Yarns, as indicated in 1 or 2 above, with addition of synthetic polymer fibers.

5. Yarns, as indicated in 1 or 2 above, with addition of ceramic fibers which were coated with a thin, up to 0.5 micron layer of carbon/graphite.

It is preferable that the yarns consist of continuous filament fibers.

The heating element core utilizes a woven product in its final form, therefore eliminating a step of treatment of the whole core material with stabilizing substances, prior to cutting of patterns, from the heating element manufacturing process.

Fig. 9A shows a woven electro-conductive heating element core (111) in a form of a strip, folded and patterned as dictated by the heating element design. Portions of the heating element core (111) may be conditioned in various locations to augment the electrical resistance of the finished product, such conditioning is performed by at least one of the following methods:

a. the use of electroconductive adhesive (122), preferably

graphite based;

b. the use of non-electroconductive coating material (118), preferably having adhesive properties.

c. making of cut outs of various shapes and sizes (117)

In order to control overheating, at least one power control device (115) is placed along the length of the heating element core.

The bends and folds along the length of the heating element core are attached by at least one of the following shape holding methods:

a. sewing (112) with electroconductive threads, preferably carbon fiber based, or sewing with non-conductive threads;

b. stapling (112');

c. gluing

d. riveting

e. fusing or sealing by insulating material during lamination of the heating element core.

As shown in Fig. 9B the heating element core is energized through a power cord (114) which is connected to the heating element with electrodes (113), preferably having a flat shape, with large contact area. The electrodes are attached to the ends of the heating element core (111), conditioned with electroconductive adhesive (122), said ends are folded over in order to have contact with both sides of the electrodes (113), then the electrode assembly is finished by sewing, stapling, riveting, or using a toothed connector.

In addition to the electrodes, the power cord has the following attachments, shown in Fig. 9A:

a. electrical plug (116)

b. optional power control device (115)

Depending on the end use of the heating element, the manufacturing process utilizes the following assembly operations in any sequence:

a. folding and shaping the core material into a predetermined shape;

b. attachment of the electrodes and the power cord;

c. laminating between the insulating material layers;

It is preferable to utilize a heat radiating layer on one side of the insulated heating element core if dictated by the heating element design; such heat radiating layer may be an aluminum foil or metallized polymer, electrically insulated from the electroconductive heating element core.

Figure 10A shows the heating element core (111) in a form of the strips, zigzagged by folding in order to vary the electrical resistance and wound around the parallel longitudinal electrodes (113). This enables the variation of the heating element's electrical resistance without varying the heating element core material. The ends of the strips (111) are attached to the electrical busses (113) by sewing (112), stapling (112') or riveting.

Electrode connectors (121) and a power cord (114) are attached to the ends of the parallel bus electrodes (113). The lamination

of the assembly between layers of electrically insulating material follows the connection of the electrode connector (121) to the ends of the heating element core (111). In order to connect the electrodes after the lamination process, when dictated by the heating element design, the insulating layer(s) shall be either stripped at the points of connection or punctured by the electrode connector (121).

Figure 10B demonstrates a variation of the heating element shown in Figure 10A. However, instead of zigzagged strips (111), folded and disposed between the electrical bus electrodes (113), the strips (111) have a straight run and are wound around the parallel bus electrodes (113). The contact between the strip and the busses is conditioned with a localized use of conductive adhesive, preferably carbon/graphite based, then secured by stapling (112) and/or sewing through the strip and the bus. The run of the zigzag, the distance between the peaks, may vary even in the same heating element, thereby varying the finished element temperature density, as may be dictated by the heating element design.

Figure 11 shows a heating element core (111) utilizing cut-outs (117) in order to: (a) achieve the variation of the electrical resistance (b) to provide for tight and hermetic lamination of the heating element core by fusing the insulating layers (123) through said cut outs. The cut outs (117) may also be filled with conductive carbon carrying substances such as positive temperature coefficient materials (PTC). The electrical bus

electrodes (113) are disposed longitudinally on the heating element core. They are made of metal wires or woven non-metallic strips with low electrical resistance or combination thereof.

The high electrical resistance of the fabric of the heating element core (111) can be achieved through addition of threads with high electrical resistance during the fabric weaving process, and through making cut-outs (117) in the body of the heating element core. The electrodes (113) are wrapped with the woven heating element core (111) and sewn with either conductive or non-conductive threads capable of withstanding the maximum heat generated by the heating element. Staples (112) can also be used for this purpose.

It is preferable to apply a carbon/graphite carrying adhesive to secure a good electrical contact between the bus electrodes (113) and the woven non-metallic heating element core (111). The heating element assembly is then followed by lamination with the insulating materials and attachment of the electrode connectors and power cord with an optional controller, to the bus electrodes (113).

Figures 12A and 12B show variations of the electrical busses designs and their attachments.

Figure 12A shows a detail of a heating element core (111), prior to lamination with insulating materials, having high conductivity threads or thin metal wires woven or sewn into its body to form the parallel electrical buss assembly (113).

An optional positive temperature coefficient (PTC) material

(119) may be incorporated longitudinally into the heating element core (111) in selected areas. Such areas have the yarns woven in such manner that the electrical resistance across said areas is lower than the resistance of adjacent areas of the woven heating element core (111).

As an example, in order to achieve lower electrical resistance of said selected areas, the weaving process shall, for such selected areas, use partially conductive or nonconductive yarns, such as ceramic or polymers. Further, the incorporated PTC material (119) introduces an additional self-limiting electrical conductivity to said selected areas of the heating element core (111). It is preferable to incorporate the PTC material longitudinally either in the center of the heating element core or next to the longitudinal bus electrodes (113). Generally, the PTC material is made of a polymer substance having electroconductive carbon-carrying filler.

Figure 12B shows a detail of a heating element core (111), prior to lamination with the insulating materials, with optional cut-outs (117), attached to woven bus strip electrodes (113) with low electrical resistance. Such an attachment is made by sewing (120), stapling or riveting. It is preferable to condition the place of said connection with electroconductive adhesive comprising carbon/graphite particles prior to attachment. An optional PTC material (119) may be utilized as described in Figure 12A.

Figure 13 shows a fragment of the heating element, prior to lamination with insulating materials, having at least three bus

electrodes (113) and having the PTC material (119) longitudinally disposed between one set of bus electrodes (113), said heating element is electrically connected in parallel. The preferred method consists of having no PTC material between one set of bus electrodes and having PTC material (119) longitudinally disposed between another set of bus electrodes (113).

All three bus electrodes (113) are connected to one power source through a power controller (115). This setup enables quick gain in temperature by bypassing one bus electrode and a zone comprising the PTC material (119). When the desired temperature of the heated object is achieved, the electrical contact is switched to the bus electrodes so as to provide the heater, by directing the current through the PTC material (119), with self-limiting temperature capabilities.

As an alternative a PTC material with the same or different temperature limit may be longitudinally disposed in the area indicated above as having no PTC material. This will provide for a heater with two, preferably different, temperature zones, each having the self-limiting temperature control capabilities. This method allows for a heating element with multiple temperature zones bordered by bus conductors.

As shown in Figure 14 the heating element core between the bus electrodes (113) may contain two or more separate fragments of woven electroconductive material (111) having PTC material (119) connecting said fragments longitudinally and providing electrical continuity. The location of the PTC material is dictated by the

heating element design.

The two adjacent fragments of the woven heating element core (111) are first connected by sewing (120) to electrically non-conductive connection strip (125), leaving a gap of predetermined width between them. The gap is then bridged with softened PTC material (119) so as to penetrate the matrix of the woven fabric of the fragments of the heating element core (111) at the edges. The sewn connection strip (125) provides desired mechanical strength; the PTC material (119) provides electrical continuity and desired self-limiting temperature control. An insulating layer (123) envelops the assembly; it may also be used for connecting said adjacent fragments of the heating element core (111) instead of the connection strip (125).

Figure 15 shows an optional detail of the heating element core (111) attachment to a bus electrode (113). In this detail the bus electrode is embedded in the PTC material (119); the shape of the PTC material envelop (119) varies with the heating element design. The edge of the heating element core (111) is then wrapped around said bus electrode (113) and PTC material (119), and secured by the shape holding means such as sewing (120), stapling or riveting. The connection between the PTC material and heating element core may also be heat sealed or fused. The insulation layer (123) envelops the whole electroconductive assembly.

Figure 16 shows a fragment of the insulated heating element core (111) comprising a strand of threads or a woven rope and a preferred embodiment of its connection with a metal electrical

connector (121) and a power cord (114). The heating element core (111) consists of a strand or rope comprising electrically conductive carbon/graphite or carbon/graphite coated ceramic threads or combination thereof. The non-electroconductive ceramic or polymer threads or combination thereof may be included in the strand or the rope of said core in order to impart additional mechanical strength and electrical resistance.

The electroconductive core (111) is then enclosed by the insulating sleeve (123). Due to a softness of the heating element core (111), it is preferable to make the electrical connection with the metal connector (121) by penetration of a thin part of the connector, having shape of a thin insert (124), such as a tooth, a screw or a needle, through a transverse cut of the insulated heating element core. After penetration of such thin electroconductive insert (124) into the body of the heating element core (111), the electrode connector (121) and the insulated heating element core are attached by crimping.

The sides of the electrode connector may also include teeth (126) which penetrate into the body of the heating element core (111) by puncturing through the insulator (123) during crimping, thus providing additional electrical connection. The electrode connector (121) may be utilized to provide electrical continuity between two segments of said heating element core or to connect one segment of a power cord and a segment of said heating element core. The same type of the electrical connection may be applied for the insulated strip, sleeve or pipe heating element core described in

this invention.

Another variation of the electrode attachment, proposed in this invention, consists of stripping the insulation (123) from the ends of the insulated heating element core (111) and attaching the electrode connector (121) to the core by crimping. It is preferable to condition the ends of the threads with electroconductive adhesive before attaching the electrode connector. It is also preferable that electroconductive adhesive comprises carbon/graphite particles.

Figure 17A shows a perspective view of a sleeve/pipe shaped heating element core (111) having bus electrodes (113'), electrically connected in series according to the preferred embodiment of the present invention;

Figure 17B describes a perspective view of a sleeve/pipe shaped heating element core (111) having longitudinal bus electrodes (113'), electrically connected in parallel.

Figure 17C shows a perspective view of a sleeve/pipe shaped heating element core (111), electrically connected in parallel, having bus electrodes (113') and an optional PTC material (119) incorporated longitudinally into said heating element core;

The installation of the bus electrodes (113'), the PTC material (119) and lamination with insulating materials may be conducted as explained above for other types of heating elements. For devices designed to heat pipe-type objects, it is preferable to have one longitudinal cut in the described sleeve heating element core for ease of installation of the heating element on said

pipe-type objects.

The proposed soft non-metallic heating elements may be utilized in a variety of commercial and industrial heater applications, using direct or alternating current. The main advantages of the heating elements are the high reliability and safety which are provided by the tightly sealed soft and durable electrically conductive yarns.

Further, the use of electrically conductive carbon/graphite fibers, non-conductive ceramic or polymer fibers in the heating element has the following additional advantages:

it enables manufacturing of thin, soft and uniform heaters without utilizing conventional metal heater wires;

it provides high durability of the heating appliances which can withstand sharp folding, small perforations, punctures and compression without decreasing of electrical operational capabilities;

it provides high tear and wear resistance owing to: (a) high strength of the conductive yarns and (b) tight hermetically enveloping around all electrically conductive media with strong insulating materials;

it provides for manufacturing of corrosion and erosion resistant heating element owing to: (a) high chemical inertness of the carbon/graphite and ceramic yarns, (b) hermetic polymer insulation of the whole heating element including connection electrodes and temperature control devices, for utilization in chemically aggressive industrial or marine environments;

it offers versatility of variation of the electrical conductivity of the heating element core owing to: (a) weaving or stranding of the electrically conductive carbon/graphite yarns to the predetermined width and thickness of the strips, sleeves, ropes or strands of threads; (b) weaving of the yarns to the predetermined density or type of weaving; (c) weaving or stranding of the carbon/graphite yarns having different electrical conductivity in one unit; (d) weaving or stranding of the carbon/graphite yarns with nonconductive ceramic and/or polymer threads or fibers; (e) making cut outs of different shapes to vary the electrical resistance of the heating element core; (f) incorporating conductive carbon/graphite coated ceramic fibers or threads;

it provides for saving of electric power consumption owing to: (a) installation of heat reflective layer, and (b) possibility of placing the heating element with less cushioning and insulation closer to the human body or to the heated object;

it allows for manufacturing of heating element with electrical connection of electrically conductive strips, ropes, sleeves/pipes or strands in parallel or in series;

it overcomes the problem of overheated spots owing to (a) high heat radiating surface area of the heating element core, (b) uniform heat distribution by the heat reflective layer, preventing the possibility of skin burns or destruction of the insulating layers;

it provides for extremely low thermal expansion of the heating

element owing to the nature of the carbon/graphite, polymer or yarns. This feature is extremely important for construction applications (Example:-concrete) or for multi-layer insulation with different thermal expansion properties;

it consists of a non-combustible electrically conductive carbon/graphite and carbon/graphite coated ceramic yarns which do not cause arcing while being cut or punctured during electrical operation;

it offers high degree of flexibility and/or softness of the heating appliances depending on the type and thickness of insulation; and

it provides technological simplicity of manufacturing and assembling of said heating element.

Further, a combination of the electrically conductive carbon/graphite carrying woven yarns and PTC material allows to: (a) provide temperature self-limiting properties of the soft heating appliances, eliminating need for thermostats; (b) increase the distance between the bus electrodes, decreasing the risk of short circuit between said bus electrodes; (c) provide dissipation of an excess heat through the highly thermally conductive carbon/graphite fibers; (d) provide larger heat radiating area resulting in higher efficiency of the heater; (e) provide a barrier for liquid penetration to the parallel bus conductors in the event of puncturing the insulated heating element core.

The process of manufacturing of the insulated heating element can be fully automated, it utilizes the commercially available non

toxic, nonvolatile and inexpensive products. The insulated heating core can be manufactured in rolls or spools with subsequent cutting to desired sizes and further attachment of electric power cords and optional power control devices.

Further, the proposed heating element can be utilized in, but not limited to: (a) electrically heated blankets, pads, mattresses, spread sheets and carpets; (b) wall, furniture, ceiling and floor electric heaters; (c) vehicle, scooter, motorcycle, boat and aircraft seat heaters; (d) electrically heated safety vests, garments, boots, gloves, hats and scuba diving suits; (e) food (Example: pizza) delivery and sleeping bags; (f) refrigerator, road, roof and aircraft/helicopter wing/blade deicing systems, (g) pipe line, drum and tank electrical heaters, (h) electrical furnace igniters, etc. In addition to the heating application, the same carbon/graphite carrying heating element core may be utilized for an anti static protection.

Figure 18A shows a garment (128) including a soft heating element according to one of the embodiments of the present invention in its construction to provide a desired degree of warmth. The soft heating element (127) is sewn (120) into the garment in a predetermined location.

Figure 18B shows a vehicle seat (129) including a soft heating element according to one embodiment of the present invention. The heating element (127) is placed under the seat upholstery.

Figure 18C demonstrates a floor assembly (130) utilizing one of the embodiments of the present invention. The heating element

(127) is placed under the floor covering. An optional power control device (115) can be utilized an any proposed heating element assembly.

Figure 18D shows a length of pipe including a soft heating element (127) according to the present invention wrapped around the pipe to provide a desired degree of heating.

The aforementioned description comprises different embodiments which should not be construed as limiting the scope of the invention but, as merely providing illustrations of some of the presently preferred embodiments of the invention. Additional contemplated embodiments include: (a) in addition to carbon/graphite yarns the heating element core may include other electrically conductive materials other than carbon, such as copper, nickel or tin containing materials; (b) heating element core may include yarns made of ceramic fibers, such as alumina, silica, boria, zirconia, chromia, magnesium, calcia, silicon carbide or combination thereof; (c) heating element core may comprise electrically conductive carbon/graphite coated ceramic fibers, such as alumina, silica, boria, zirconia, chromia, magnesium, calcia, silicon carbide or combination thereof; (d) the strips can be soaked in a diluted solution of adhesives and dried, to ease the hole cutting during manufacturing of the heating element core and augmentation of its electrical properties; (e) the heating element core may comprise the conductive strips, ropes, sleeves/pipes or threads, having different electrical resistance; (f) the heating element core may be formed into various patterns

such as serpentine or other desired patterns, including ordinary straight, coil or "U" shaped forms; (g) the electric power cord can be directly attached to the conductive heating element core without the use of electrodes, it is preferable to utilize electrically conductive adhesive, conductive paint, conductive polymer, etc. to assure good electrical connection; (h) the conductive heating element core can be electrically insulated by the soft non-conductive fabrics or polymers by sewing, gluing, fusing etc., forming a soft multi-layer assembly; (i) the conductive soft heating element core can be electrically insulated by rigid non-conductive materials like ceramics, concrete, thick plastic, wood, etc.; (j) the shape holding means can be applied on any part of the heating element core.

While the foregoing invention has been shown and described with reference to a number of preferred embodiments, it will be understood by those possessing skill in the art that various changes and modifications may be made without departing from the spirit and scope of the invention.

CLAIMS:

1. A method of manufacturing a heating element comprising the steps of:

impregnating a soft material into a carbon carrying fabric forming an impregnated fabric;

curing said soft material so as to stabilize said impregnated fabric to enable cutting to a desired shape;

cutting said impregnated fabric into a desired predetermined shape;

conditioning each of at least two ends of said impregnated fabric;

attaching conductive means for introducing an electric current to each of said conditioned ends of said fabric; and

laminating said impregnated fabric between at least two layers of insulating material so as to envelop said impregnated fabric and said conductive means providing a seal therebetween.

2. The method of manufacturing a heating element according to claim 1, wherein said soft material is impregnated into said soft material by soaking said soft material into a solution of said soft material.

3. The method of manufacturing a heating element according to claim 1, wherein said impregnated material is pressed out by advancing said fabric through at least two rollers having an adjustable pressure function.

4. The method of manufacturing a heating element according to

claim 3, wherein after said fabric is pressed out said fabric is heat treated by applying hot air to at least one side thereof.

5. The method of manufacturing a heating element according to claim 3, wherein after said fabric is pressed out said fabric is heat treated by advancing said fabric through at least one hot roller having an adjustable temperature setting.

6. The method of manufacturing a heating element according to claim 1, wherein said soft material is impregnated into said fabric by spraying said soft material over at least one side of said fabric.

7. The method of manufacturing a heating element according to claim 1, wherein said soft material is impregnated into said fabric by applying a thin polymer film to at least one side of said fabric.

8. The method of manufacturing a heating element according to claim 1, wherein the step of conditioning said ends of said impregnated fabric comprises the step of removing said soft material from said ends of said impregnated fabric.

9. The method of manufacturing a heating element according to claim 1, wherein said step of conditioning further comprises the step of applying an electrically conductive carbon carrying substance onto said ends of said impregnated fabric.

10. The method of manufacturing a heating element according to claim 1, wherein further comprising the step of connecting a power cord to at least one of said conductive means.

11. A substantially soft and flexible heating element comprising:

an electrically conductive carbon carrying fabric of a predetermined shape extending from one end to another;

a soft filling material impregnated in said carbon carrying fabric adapted to stabilize said fabric;

a conductive means for introducing an electric current to said fabric; and

an insulating means for insulating said fabric.

12. The heating element according to claim 11, wherein said carbon carrying conductive fabric is a woven fabric.

13. The heating element according to claim 11, wherein said carbon carrying conductive fabric is a non-woven fabric.

14. The heating element according to claim 11, wherein said soft filling material is made of a nonvolatile and nonconductive organic substance.

15. The heating element according to claim 11, wherein said soft material is made of a starch.

16. The heating element according to claim 11, wherein said soft material is made of an electrically conductive carbon carrying material.

17. The heating element according to claim 11, wherein said predetermined shape is a serpentine pattern.

18. The heating element according to claim 11, wherein said predetermined shape has a zigzag pattern.

19. The heating element according to claim 11, wherein said

predetermined shape has a spiral pattern.

20. The heating element according to claim 11, wherein said heating element further comprises:

a reflective metallic layer disposed on said insulating layer and electrically insulated from said fabric.

21. The heating element according to claim 11, wherein said conductive means comprises at least two electrodes one each attached to said ends of said impregnated fabric.

22. The heating element according to claim 11, wherein said insulating means comprises an insulating layer enveloping said fabric and said pair of electrodes to hermetically seal said fabric and said electrodes therewithin.

23. A heating element comprising:

electrically conductive nonmetallic yarns, including at least carbon fibers, assembled into a soft material of continuous longitudinal shape during textile fabrication; said soft material is cut to a predetermined length and laid out into a predetermined pattern;

a conductive means for introducing an electrical current to said soft material;

an insulating means for insulating said electrically conductive soft material with at least one layer of nonconductive means.

24. The heating element according to claim 23, wherein said carbon fibers comprise graphite fibers.

25. The heating element according to claim 23, wherein said

soft material comprises nonconductive polymer fibers.

26. The heating element according to claim 23, wherein said soft material comprises ceramic fibers.

27. The heating element according to claim 23, wherein said soft material comprises electrically conductive carbon coated ceramic fibers.

28. The heating element according to claim 23, wherein said continuous, electrically conductive soft material is a woven strip.

29. The heating element according to claim 23, wherein said continuous, electrically conductive soft material has a shape of a woven pipe.

30. The heating element according to claim 23, wherein said continuous, electrically conductive soft material is a woven rope.

31. The heating element according to claim 23, wherein said continuous, electrically conductive soft material is a strand of threads.

32. The heating element according to claim 23, wherein said soft material is laid out into a predetermined pattern, forming gaps between fragments of said soft material.

33. The heating element according to claim 23, further including conditioned local spots for providing diversity and control of electrical resistance in selected areas of said soft material.

34. The heating element according to claim 33, wherein said conditioned local spots are the selected areas, filled with electrically conductive graphite carrying substance.

35. The heating element according to claim 33, wherein said conditioned local spots are the selected areas cut out of said electrically conductive soft material.

36. The heating element according to claim 33, wherein said conditioned local spots are the selected areas, filled with a nonvolatile, nonconductive organic substance.

37. The heating element according to claim 33, wherein said conditioned local spots are the selected areas, comprising a positive temperature coefficient material for providing temperature self limiting capabilities to said heating element.

38. The heating element according to claim 23, further including:

at least two bus conductors, running through the full length of said element,

at least one fragment of said heating element comprising positive temperature coefficient material and at least one fragment of woven electroconductive material, comprising carbon fiber yarns, disposed longitudinally between at least two of said bus conductors so that each one of said positive temperature coefficient material fragments directly connects to not more than one of said bus conductors.

39. The heating element according to claim 38, wherein said positive temperature coefficient material connects to said bus conductors by embedding said bus conductor in said positive temperature coefficient material.

40. The heating element according to claim 23, further

including a shape holding means for connecting and holding the fragments of said soft material in the predetermined pattern.

41. The heating element according to claim 40, wherein said shape holding means comprises stapling.

42. The heating element according to claim 40, wherein said shape holding means comprises sewing.

43. The heating element according to claim 40, wherein said shape holding means comprises fusing with an insulating material.

44. The heating element according to claim 23, wherein said conductive means is electrically conductive adhesive for electrically connecting said soft material with electrical conductors.

45. The heating element according to claim 23, wherein said conductive means is an electrical conductor having a conductive insert penetrating into the body of said soft material through a transverse cut through the insulated heating element core.

46. The heating element according to claim 23, wherein said conductive means are thin metal wires incorporated into the body of said soft material to form bus conductors.

47. The heating element according to claim 23, wherein said conductive means comprises at least two metallic electrode conductors surrounded by said soft material.

48. The heating element according to claim 23, wherein said soft material is laid out in a zigzag pattern, wound around at least two electrical bus conductors and electrically connected in parallel.

49. The heating element according to claim 23, further including a heat reflecting layer, placed on at least one side of said heating element, and electrically insulated from said soft material and said conductive means.

50. A heating element having a soft and durable construction for incorporation into a plurality of articles, said heating element comprising:

a soft material comprising electrically conductive nonmetallic yarns, said yarns including carbon fibers;

a conductive means for introducing an electrical current to said soft material;

an insulating means for insulating said electrically conductive soft material with at least one nonconductive layer.

51. The heating element according to claim 50, wherein said soft material is fabricated to have a continuous longitudinal shape.

52. The heating element according to claim 50, wherein said carbon fibers comprise graphite fibers.

53. The heating element according to claim 50, wherein said soft material comprises nonconductive polymer fibers.

54. The heating element according to claim 50, wherein said soft material is a woven strip.

55. The heating element according to claim 50, wherein said soft material has a shape of a woven pipe.

56. The heating element according to claim 50, wherein said soft material is a woven rope.

57. The heating element according to claim 50, wherein said soft material is a strand of threads.

58. The heating element according to claim 50, wherein said soft material engages at least two electrical bus conductors and is electrically connected in parallel.

59. The heating element according to claim 50, further including a heat reflecting layer, placed on at least one side of said heating element, and electrically insulated from said soft material and said conductive means.

60. The heating element according to claim 50, further including selected areas, comprising a positive temperature coefficient material for providing temperature self limiting capabilities to said heating element.

61. The heating element according to claim 50, wherein said conductive means comprises at least two metallic electrode conductors surrounded by soft material.

62. The heating element according to claim 50, wherein said conductive means are thin metal wires incorporated into the matrix of said soft material to form a bus electrode assembly.

63. The heating element according to claim 50, wherein said conductive means is an electrode connector having a conductive insert penetrating into the body of said soft material through a transverse cut through the insulated heating element core.

64. The heating element according to claim 50, further including a heat reflecting layer, placed on at least one side of said heating element, and electrically insulated from said soft

material and said conductive means.

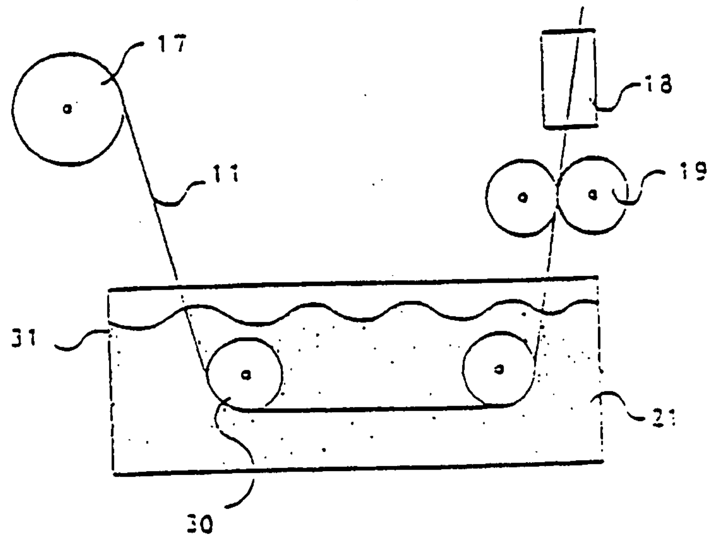

FIG. 1

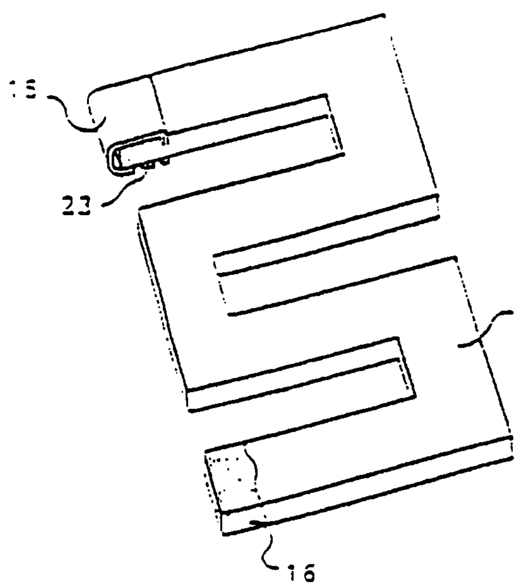

FIG. 2

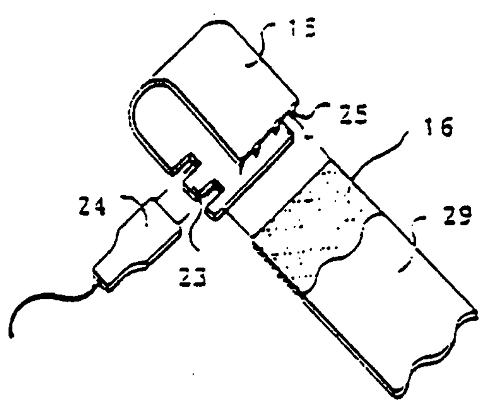

FIG. 3

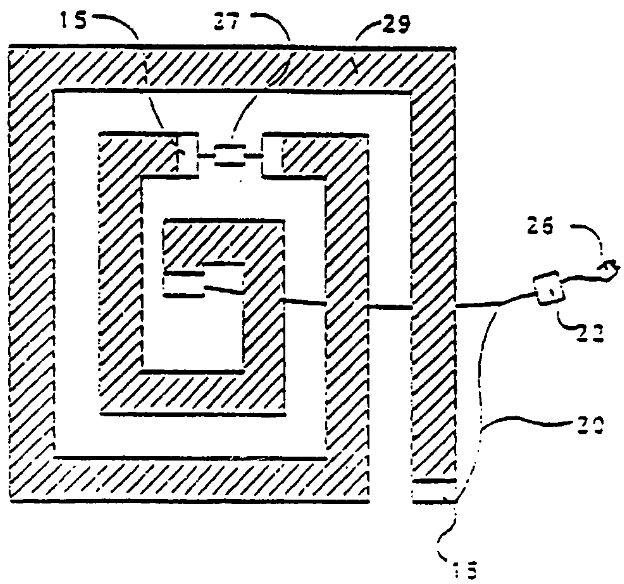

FIG. 4

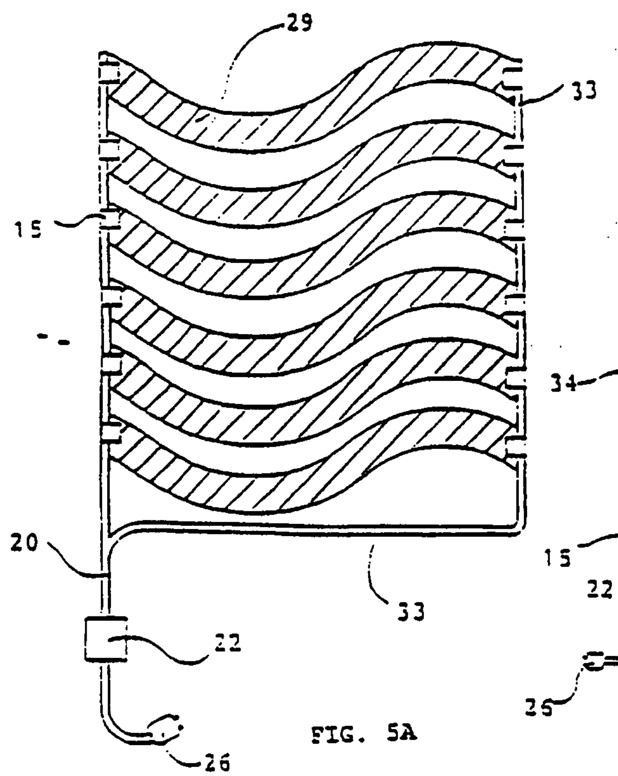

FIG. 5A

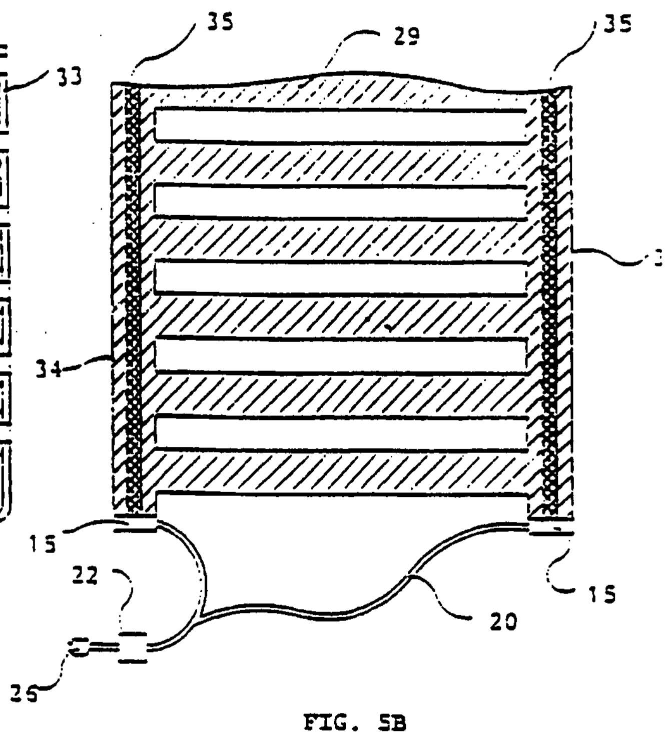

FIG. 5B

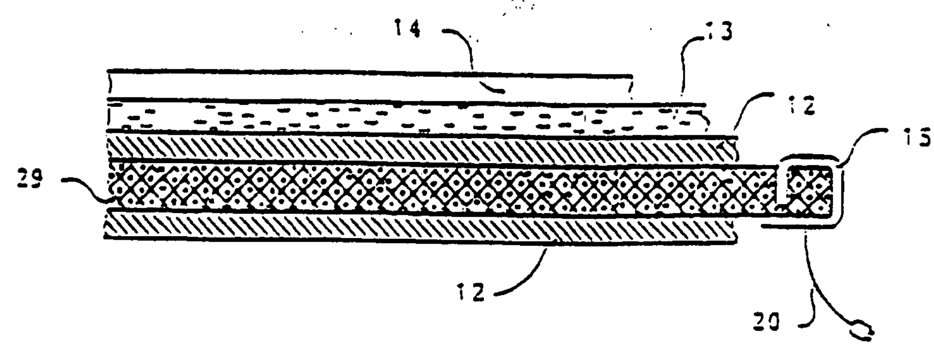

FIG. 6

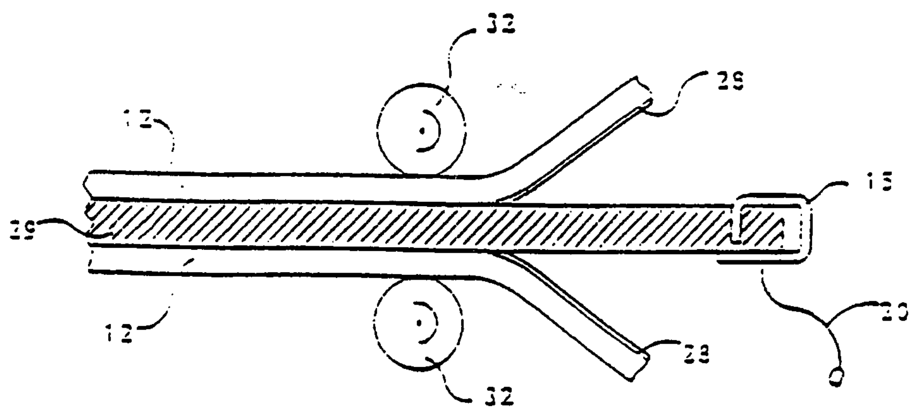

FIG. 7

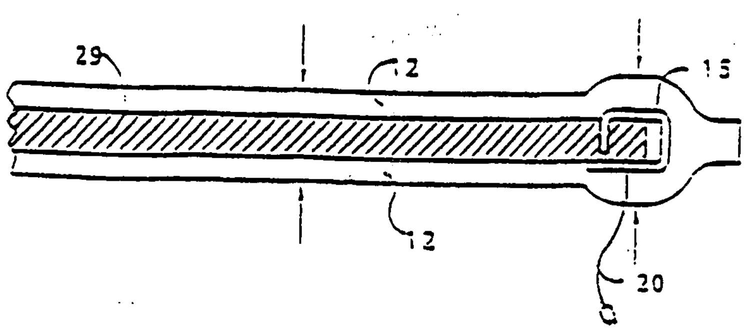

FIG. 8

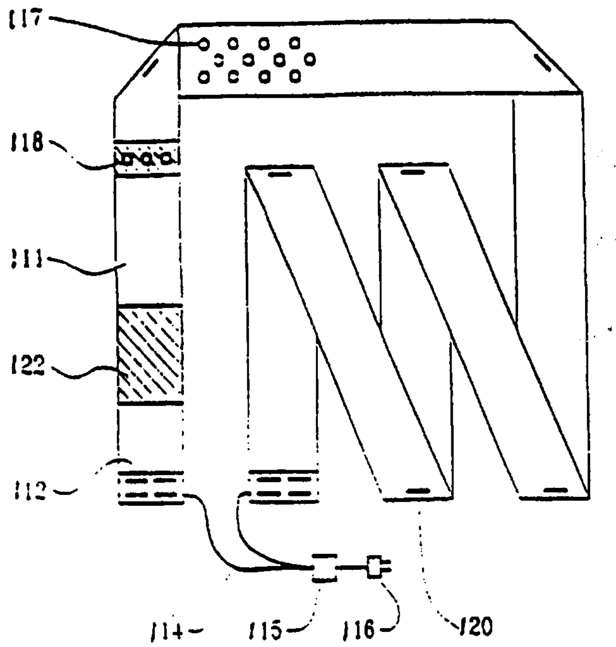

FIG. 9A

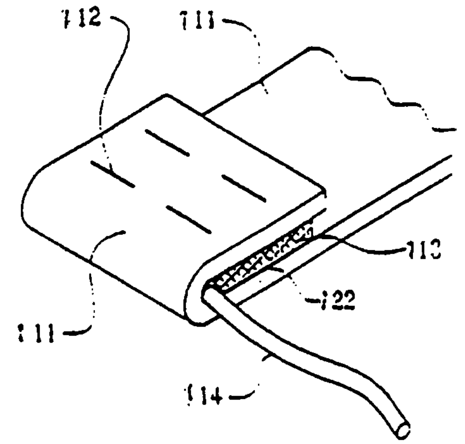

FIG. 9B

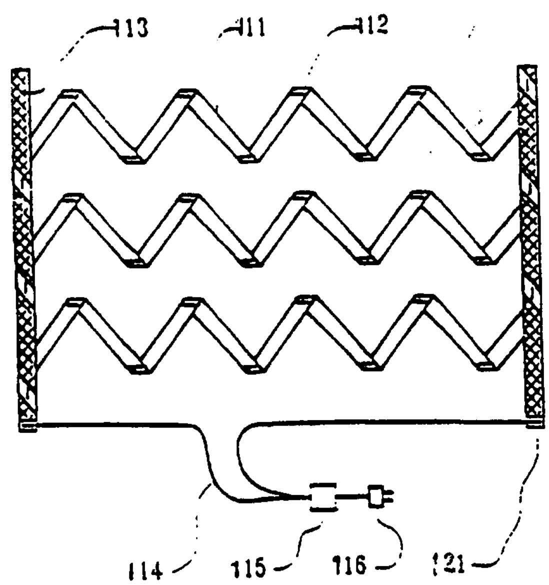

FIG. 10A

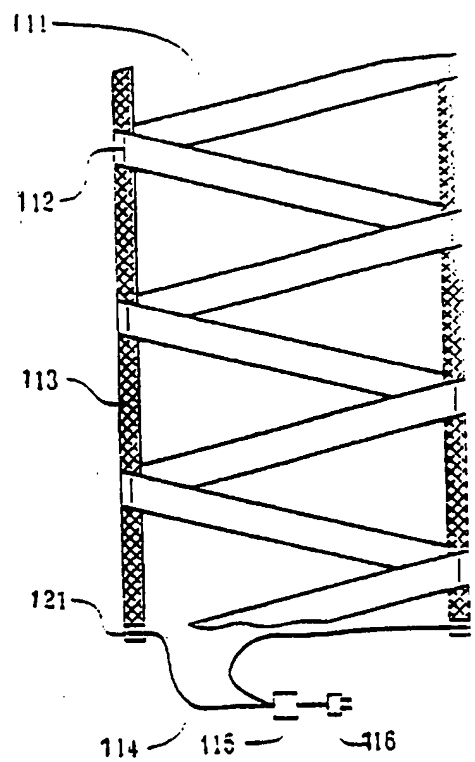

FIG. 10B

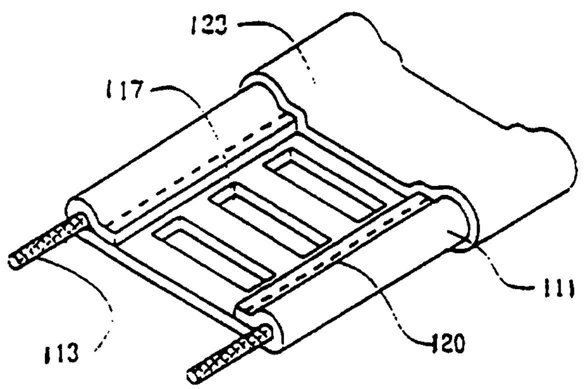

FIG. 11

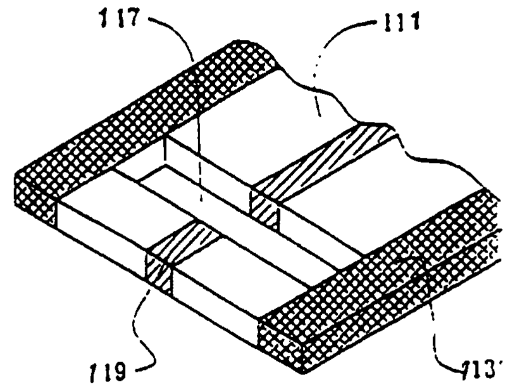

FIG. 12A

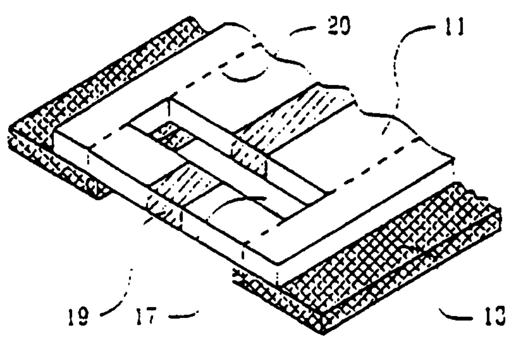

FIG. 12B

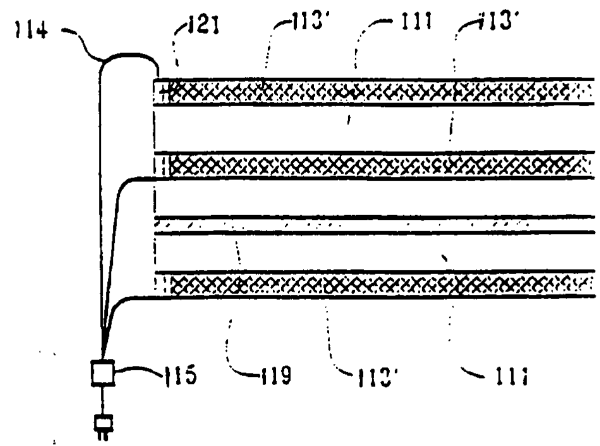

FIG. 13

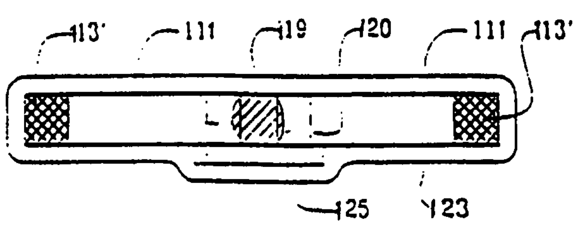

FIG. 14

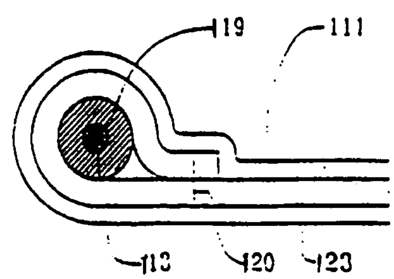

FIG. 15

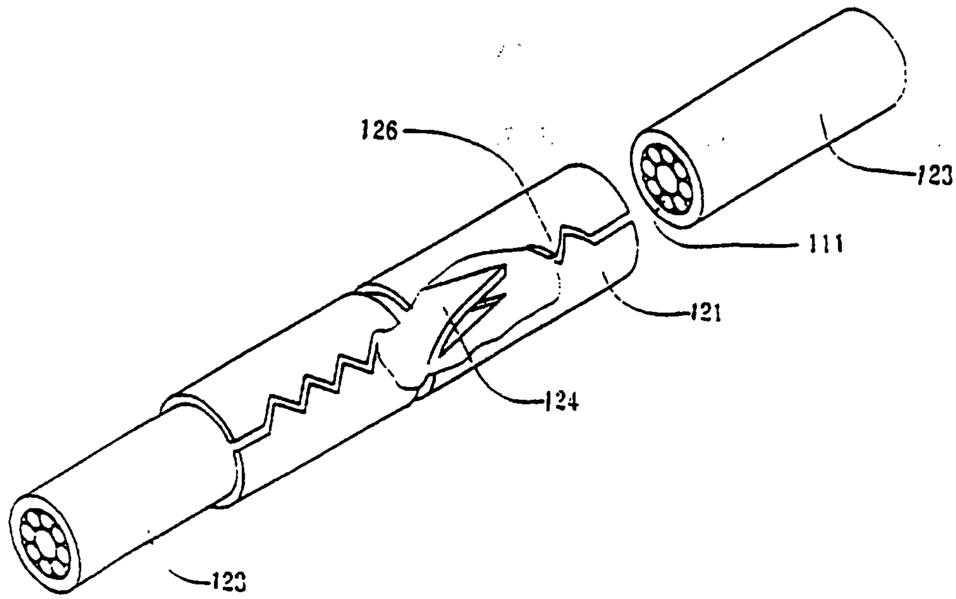

FIG. 16

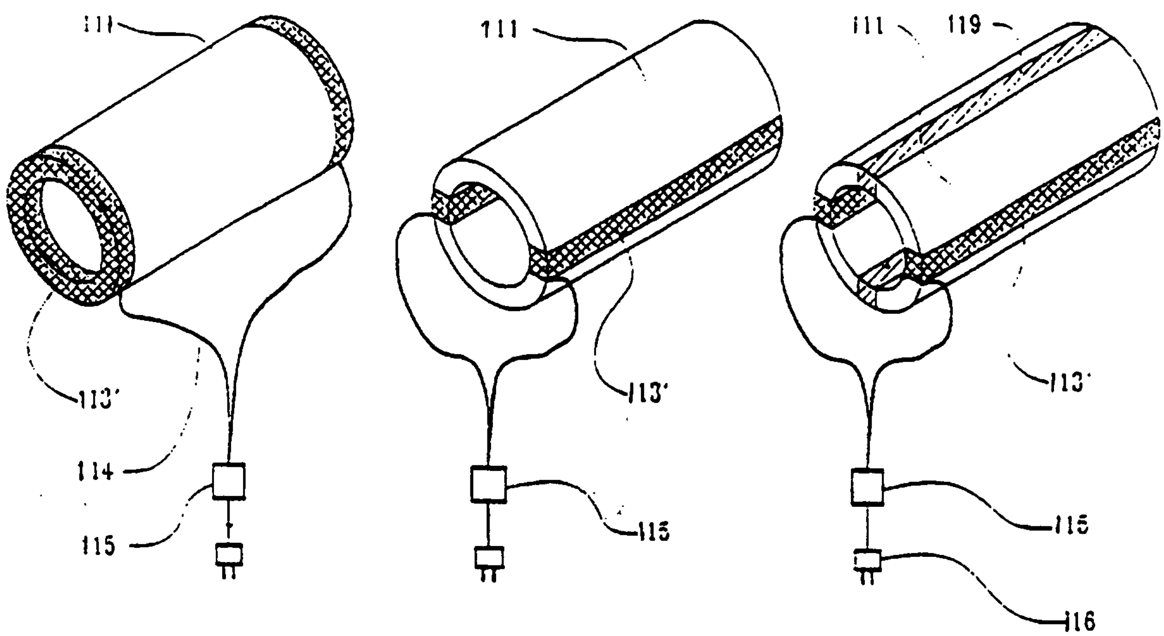

FIG. 17A FIG. 17B FIG. 17C

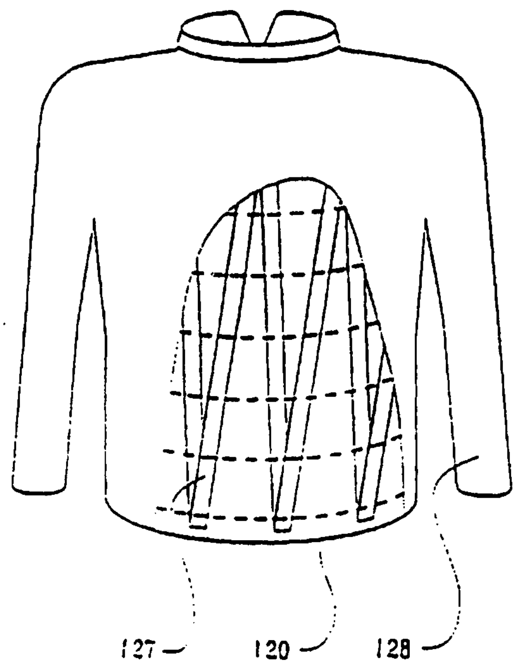

FIG. 18A

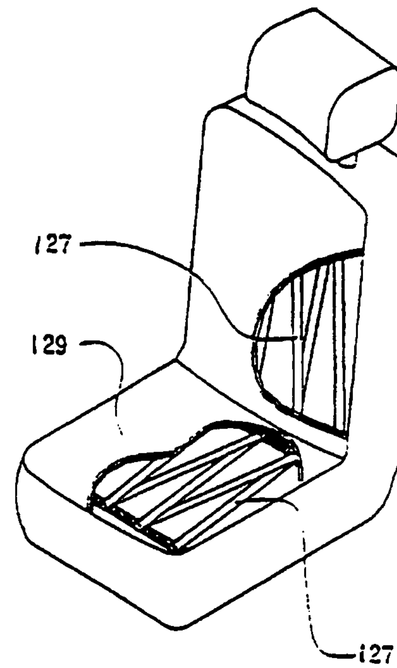

FIG. 18B

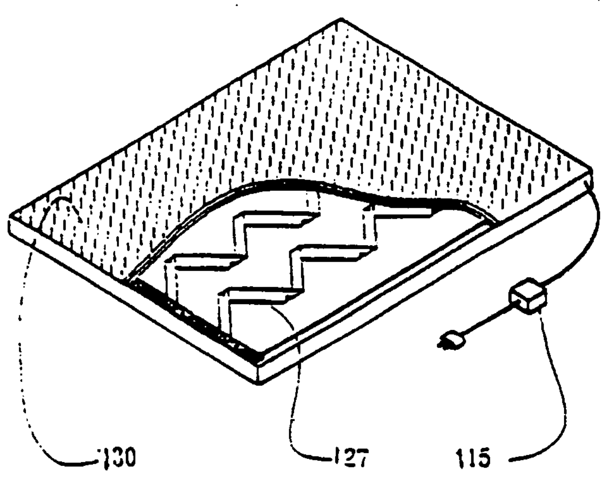

FIG. 18C

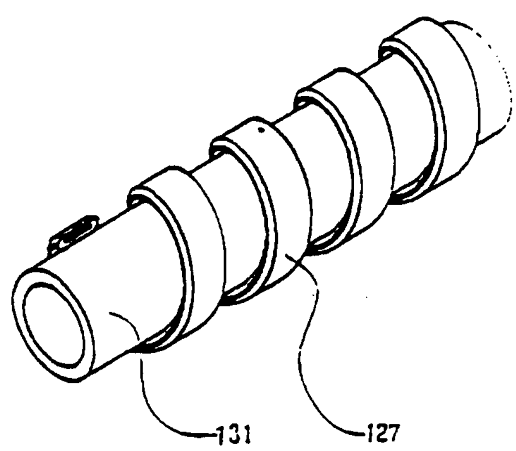

FIG. 18D

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15291

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H05B 1/00, 3/00, 3/06, 3/10, 3/16, 3/34; H01C 17/00, 17/06
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 219/211, 212, 527, 528, 529, 542, 543, 545, 548, 549; 29/610.1, 611, 620

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

USPTO APS, STN

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y --- A	US 4,250,397 A (GRAY ET AL) 10 FEBRUARY 1981 (10/02/1981), SEE COLUMN 4 TO COLUMN 5, AND SEE FIGURE 2A.	1-15, 17-19, 21-22 ---------- 16, 20 ---------- 33-39
X --- Y	US 4,983,814 A (OHGUSHI ET AL) 08 JANUARY 1991 (08/01/1991), SEE COLUMN 3, LINES 11-37; COLUMN 5, LINES 23-34; COLUMN 7, LINES 53-61; COLUMN 10, LINES 13-53.	23-25, 28-32, 45-48, 50-58, 60-63 ---------- 16, 26-27, 40-44, 49, 59, 64
X	US 3,349,359 A (MOREY) 24 OCTOBER 1967 (24/10/1967), SEE COLUMN 3, LINES 39-55, AND SEE FIGURE 2.	23-28, 31-32, 50-54, 57-58

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 OCTOBER 1997	19 NOV 1997

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	SAM PAIK
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15291

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,935,422 A (BARNES ET AL) 27 JANUARY 1976 (27/01/1976), SEE COLUMN 2, LINES 1-11.	16
Y	US 5,298,722 A (TANAKA) 29 MARCH 1994 (29/03/1994), SEE COLUMN 5, LINES 15-20).	20, 49, 59, 64
Y	US 4,825,049 A (RICKBORN) 25 APRIL 1989 (25/04/1989), SEE COLUMN 2, LINES 20-34.	26-27
Y	US 5,023,433 A (GORDON) 11 JUNE 1991 (11/06/1991), SEE COLUMN 3, LINES 35-45.	40-42, 44
Y	US 3,385,959 A (AMES ET AL) 28 MAY 1968 (28/05/1968), SEE COLUMN 2, LINES 53-59 AND SEE FIGURE 4.	40-42, 44
Y	US 3,774,299 A (SATO ET AL) 27 NOVEMBER 1973 (27/11/1973), SEE COLUMN 2, LINES 47-62.	43

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15291

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

219/211, 212, 527, 528, 529, 542, 543, 545, 548, 549; 29/610.1, 611, 620